IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR U.S. LETTERS PATENT

Title:

CALL ADMISSION CONTROL WITH OVERBOOKING SUPPORT AND CELL LOSS RATIO AND CELL DELAY VARIATION GUARANTEE

Inventors:

Hongbin Ji
Eraj D. Kaluarachchi
On-Ching Yue

CALL ADMISSION CONTROL WITH OVERBOOKING SUPPORT AND CELL LOSS RATIO AND CELL DELAY VARIATION GUARANTEE

BACKGROUND OF THE INVENTION

1. Field of the Invention

5   The present invention relates generally to communication systems, and more

particularly to call admission control for controlling access to ATM networks or IP

networks with support of differentiated services.

2. Description of the Related Art

An Asynchronous Transfer Mode (ATM) network is one method for realizing

10   a flexible and cost-effective network for handling a wide variety of communications.

In an ATM network, various types of data that have various transmission rates and

traffic characteristics, are multiplexed. Therefore, the multiplexed traffic load

fluctuates heavily and rapidly, especially when high speed calls are multiplexed.

Call admission control (CAC) is an important element of ATM traffic

15   management. CAC provides access by regulating the number and types of

connections that can be allowed at any given time for a given amount of resources.

In an ATM multi-service network, the resource demand of each connection has to

be estimated as a function of several variables, including the cell-level traffic

descriptors, the required quality-of-service (QOS), the states of the network

20   resources, and the traffic-stream class or priority. When a call request is made, the

ATM network determines whether the quality of service would be suitable in all connections, including connections which are already established when the call request is accepted, and determines propriety of the acceptance according to the available services. To make this determination, it is recommended that each terminal issuing a call request should declare parameters, such as an average rate (an average bandwidth) and a peak rate (a peak bandwidth), as source traffic characteristics, and the call admission control be performed using the declared parameters.

ATM admission control can be based on either of two approaches: a direct performance-evaluation approach or an inverse resource-requirement-estimation approach. In the direct approach, the estimated cell-level performance resulting from the admission of a new connection (or call) is calculated. In the inverse approach, an EBR ("equivalent bit rate," often called the "equivalent bandwidth" or "effective bandwidth") of the new arrival is determined by some artifice or another. The connection is accepted if the remaining unassigned capacity of the route is not less than the calculated EBR. The EBR for a connection which traverses several links may vary from link to link and would be based on the source's traffic descriptors, the cell-level performance objectives, the speed of the link under consideration, and the buffer size.

Thus, in the inverse approach, call admission criteria can be expressed as follows:

$$BW_{up\text{-}cbr} + BW_{up\text{-}rtvbr} + BW_{up\text{-}nrtvbr} \leq C_p \qquad (1A)$$
$$BW_{down\text{-}cbr} + BW_{down\text{-}rtvbr} + BW_{down\text{-}nrtvbr} \leq C_p \qquad (1B)$$

where $BW_{up\text{-}cbr}$, $BW_{up\text{-}rtvbr}$, and $BW_{up\text{-}nrtvbr}$ are the aggregate effective bandwidth for Constant Bit Rate (CBR), real time Variable Bit Rate (rtVBR) and non-real time Variable Bit Rate (nrtVBR) upstream traffic classes and $BW_{down\text{-}cbr}$, $BW_{down\text{-}rtvbr}$, and $BW_{down\text{-}nrtvbr}$ are the aggregate effective bandwidth for CBR, rtVBR and nrtVBR

5   downstream traffic classes, respectively, and C_p is the port bandwidth. When a new connection request, which belongs to a particular class, comes in, it is necessary to recompute the effective bandwidth for that class and then determine if the above criteria in Equations (1A) and (1B) are met.

There are problems, however, with conventional call admission control. For

10   example, in conventional call admission control systems, there is no perfect call admission control or effective bandwidth computation, as the systems generally make approximations of the traffic models. Accordingly, the systems do not have the capacity for maintaining the communication quality or for efficiently utilizing resources of the network when the systems are supplied with calls which have many

15   different traffic characteristics, making precision traffic control difficult to achieve.

SUMMARY OF THE INVENTION

The present invention provides novel call admission methods for admitting connections in communications networks such as ATM networks or emerging IP networks.

20   According to the present invention, an innovative overbooking technique is utilized which distinguishes among the different service classes. Each service class is

assigned an overbooking factor. The call admission is determined based on the overbooking factor assigned to the class and the effective bandwidth for that service class. In addition, methods are disclosed for performing appropriate bookkeeping, i.e., updating and maintaining information concerning the state of the system.

5　　　These and other advantages and features of the invention will become apparent from the following detailed description of the invention which is provided in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

　　　FIGURE 1 illustrates in flow chart form a call admission control method that

10　utilizes overbooking per service class in accordance with the present invention;

　　　FIGURES 2A and 2B illustrate in flow chart form a perfect state bookkeeping method for meeting both cell loss ratio (CLR) and cell delay variation (CDV) in accordance with the present invention;

　　　FIGURE 3 illustrates in flow chart form a method for performing perfect

15　state bookkeeping, in accordance with the present invention, when a call release is requested;

　　　FIGURES 4A and 4B illustrate in flow chart form an approximate state bookkeeping method for meeting both cell loss ratio (CLR) and cell delay variation (CDV) in accordance with the present invention;

FIGURE 5 illustrates in flow chart form a method for performing

approximate state bookkeeping, in accordance with the present invention, when a

call release is requested;

FIGURE 6A is a block diagram illustrating an access terminal used in a

5   network in which the methods of the present invention are performed; and

FIGURE 6B illustrates in block diagram form a system configuration that

includes a daisy chain arrangement of multiple access terminals illustrated in Fig. 6A.

DETAILED DESCRIPTION

The present invention will be described as set forth in the embodiments

10   illustrated in Figs. 1-6. Other embodiments may be utilized and structural, logical

or programming changes may be made without departing from the spirit or scope of

the present invention.

In accordance with the present invention, an innovative overbooking

technique is utilized which distinguishes among the different service classes. Each

15   service class is assigned an overbooking factor. The call admission is determined

based on the overbooking factor assigned to the class and the effective bandwidth

for that service class.

Fig. 1 illustrates in flow chart form a call admission control method that

utilizes overbooking per service class in accordance with the present invention. In

step 10, an overbooking factor α_i, where i is the index to the class of service, is assigned to each class of service. The default value $\alpha_i = 1$ indicates that there is no overbooking for class i. By using different overbooking factors for the different classes, the present invention distinguishes between these classes so as to maximize the bandwidth utilization of the system without sacrificing the QoS guarantee. For example, service classes typically provided with bursty traffic can be overbooked more than service classes that are typically provided with smooth traffic. The exact value that will be assigned for each class will depend on how conservative the system is desired to be. For example, for the CBR class, in which traffic characteristics are quite predictable, the overbooking factor may be close to 1, i.e., very little overbooking. For the VBR class, a value larger than 1 may be assigned to its overbooking factor, i.e., the VBR class may be overbooked more than the CBR class.

In step 20, the aggregate effective bandwidth for class i, designated C_i, is calculated. The computation of the effective bandwidth is as follows. For the CBR class, it is known in the art that a buffer size of 150 cells is sufficient to keep cell loss ratio (CLR) below 10^{-11} for a very large number of connections (about 5000) at 95% utilization. Therefore, it is reasonable to allocate this amount of buffer for the CBR class without concern for CBR traffic cell loss. Accordingly, only the cell delay variation (CDV) needs to be checked at connection admission time. Let d be the most stringent CDV requirement among CBR traffic. Further let a be the cell transmission time corresponding to the allocated CBR bandwidth. We need to ensure the QoS of CDV is guaranteed by:

$$\Pr(q_{cbr} > d/a) < \alpha \qquad (2)$$

where α denotes the desired percentile for the CDV, and q_{cbr} is the queue length of the CBR traffic. Heterogeneous CBR traffic multiplexing can be modeled as $\Sigma_i D_i/1/K$ queue. It has been shown that the queue in $\Sigma_i D_i/1/K$ can be upper bounded by the queue of an appropriate approximating $N*D/D/1/K$ queue where the latter queue has the same number of streams as the former but the streams are homogeneous (have the same period) with the common period D such that $N/D = p$, the same load factor as in the former queue. Given the existing N_{cbr} number of CBR connections with peak cell rate (PCR) being p_i and CDV requirement d_i for $i = 1, 2, \ldots, N_{cbr}$, it is necessary to find the appropriate bandwidth allocation factor BW_{cbr} such that the tightest CDV is met by solving the following equation, which gives the queue distribution in a homogeneous queue with N_{cbr} connections with period D:

$$\Pr(q_{cbr} > \alpha) = \sum_{n=\alpha+1}^{N_{cbr}} C_n^{N_{cbr}} \left(\frac{n-\alpha}{D}\right)^n \left(1 - \frac{n-\alpha}{D}\right)^{N_{cbr}-n} \frac{D - N_{cbr} + \alpha}{D - n + \alpha} < \alpha \qquad (3)$$

where x =

$$\min_{i=1}^{N_{cbr}} d_i / a, D = N_{cbr} / \frac{\sum_{i=1}^{N_{cbr}} P_i}{BW_{cbr} * ShelfPCR} \qquad (4)$$

and where a is the cell transmission time given by cell size divided by BW_{cbr} * *ShelfPCR*, where *ShelfPCR* is the feeder bandwidth of the multiplexer. Bisection or a table lookup can then be used to solve the above equation and find effective bandwidth allocation $C_i = BW_{cbr}$ for the CBR traffic class.

5   The rt-VBR traffic class can be characterized by three parameters, p_i, m_i, b_i, which represent peak cell rate (PCR), sustainable cell rate (SCR), burst size for the i-th connection for $i = 1, 2, ..., N_{rtvbr}$ where N_{rtvbr} denotes the number of established rt-VBR connections. Assuming the source is modeled by on-off periods, we can compute the average ON and OFF periods by $Ton_i = b_i/p_i$, $Toff_i = b_i/(1/m_i - 1/p_i)$.

10   The QoS requirement for rt-VBR is the cell loss ratio (CLR, denoted L_i) and the cell delay variation (CDV, denoted by d_i), where α denotes the desired percentile for the delay performance.

For loss performance, the following must be satisfied:

$$\Pr(q_{rtvbr} > B_{rtvbr}) < L_{\min} = \min_{i=1}^{N_{rtvbr}} L_i \qquad (5)$$

15   where q_{rtvbr} and B_{rtvbr} denote the queue occupancy and buffer allocation for rt-VBR traffic class, respectively. For delay performance, the following condition must be checked:

$$\Pr\left(q_{rtvbr} > \min_{i=1}^{N_{rtvbr}} d_i * BW_{rtvbr} * ShelfPCR\right) < \alpha \qquad (6)$$

Essentially, the cell delay performance checking is similar to cell loss checking. Accordingly, in the following it is only necessary to concentrate on the cell loss performance guarantee, and in Equation (6) the approach can be taken where traffic sources are assumed independent with exponentially distributed on and

5   exponentially distributed off periods. The first stage consists of computing as a function of B_{rtvbr}, L_{min}, and the traffic descriptor the following lossless effective bandwidth:

$$e_i^o = \frac{Pi}{2}\left[1 - \frac{\sigma_i}{1-\alpha_i} + \sqrt{\left(1 - \frac{\sigma_i}{1-\alpha_i}\right)^2 + 4\sigma_i \frac{\alpha_i}{1-\alpha_i}}\right] \quad (7)$$

where $x_i = m_i/p_i$ and $\sigma_i = B_{rtvbr}/(b_i\log(1/L_{min}))$.

10   In the second stage, the Gaussian approximation is used to estimate the loss probability which is given in terms of the error function by:

$$\Pr(q_{rtvbr} > B_{rtvbr}) \approx erf\left(\frac{BW_{rtvbr} * ShelfPCR - M}{\sqrt{V}}\right) < L_{min} \quad (8)$$

where

$$M = \sum_{i=1}^{Nrtvbr} m_i, V = \sum_{i=1}^{Nrtvbr} m_i\left(e_i^o - m_i\right) \quad (9)$$

and BW_{rtvbr} is the effective bandwidth factor required to guarantee the minimum cell loss ratio. Equation (8) can be solved for $C_i = BW_{rtvbr}$ by using a table lookup of inverse error function:

$$BW_{rtvbr} = \min\left(\sum_i e_i^o, M + Q^{-1}(L_{min})\sqrt{V}\right) / ShelfPCR \qquad (10)$$

5   where Q^{-1} is the Q-inverse function. The Q-function is defined as:

$$Q(\alpha) = \frac{1}{\sqrt{2\pi}\int\limits_{\alpha}^{\infty} e^{-t^2/2}dt} \qquad (11)$$

For $Q(x) = \alpha$, x can be expressed in terms of the error function as:

$$x = \sqrt{2}erf^{-1}(1-2\alpha) \qquad (12)$$

where erf^{-1} is the inverse error function.

Once the effective bandwidth C_i per service class is computed in step 20 as

10   described above, it can be determined if a call will be admitted. A call will be admitted if:

$$\sum_i \frac{1}{\alpha i} C_i \leq C_p \qquad (13)$$

where C_p is the total bandwidth of the port, or link, in the system through which the calls are passing. In step 30, the free bandwidth at the port is determined by:

$$\text{freeBW} = C_p - \sum_i \frac{1}{\alpha_i} C_i \qquad (14)$$

5   When a call is requesting to be admitted to the system, in step 40, it is determined if freeBW is greater than zero, i.e., if there is available bandwidth to admit the call. If freeBW is greater than zero, then in step 50 the call is admitted. If in step 40 it is determined that freeBW is less than zero, then in step 60 the call is rejected and entry into the system is denied.

10   Thus, in accordance with the present invention, an overbooking technique is utilized which distinguishes among the different service classes. Each service class is assigned an overbooking factor, and admission of a call is determined based on the overbooking factor assigned to the class and the effective bandwidth for that service class.

15   Once it has been determined in step 50 of Fig. 1 that a call can be admitted based on the overbooking, it is necessary to perform bookkeeping on the system to ensure that the system can handle the call if it is admitted. In accordance with the present invention, two types of bookkeeping can be performed: perfect state bookkeeping, and approximate state bookkeeping, as will be further described

20   below.

Figs. 2A and 2B illustrate in flow chart form a method for performing perfect state bookkeeping, in accordance with the present invention, when a connection setup is requested. Suppose for example there are N number of connections each of which is described by the variables (p_i, m_i, b_i), which represent the peak cell rate (PCR), sustainable cell rate (SCR) and maximum burst size (MBS) of the i-the connection which shares a buffer of B cells. These state variables are initialized to be zero in the initial phase when there is no connection. The required bandwidth must be determined to meet the following two QoS requirements:

$$\Pr(q > B) < L \qquad\qquad (15A)$$
$$\Pr(q > d^* C_{alloc}) < \alpha \qquad\qquad (15B)$$

where L is the CLR requirement, d is the CDV requirement, α is the CDV percentile, and C_{alloc} is the allocated bandwidth.

When a new connection setup request, described by p, m, and b, comes in, in step 100 the effective bandwidth to meet the CLR requirement $e0^{clr}$ is computed by

$$e0^{clr} = \frac{p}{2}\left[1 - \frac{\sigma}{1-x} + \sqrt{\left(1 - \frac{\sigma}{1-x}\right)^2 + 4\sigma\frac{x}{1-x}}\right] \qquad (16)$$

where $x_i = m_i/p_i$ and $\sigma_i = B/(b_i \log(1/L))$. In step 105, the variance of the traffic load for the CLR requirement $vclr$ is computed by

$$vclr = m^* (e0^{clr} - m) \qquad\qquad (17)$$

In step 110, the required bandwidth C_{clr} to meet the CLR requirement is computed by

$$C_{clr} = \min\left(E0_{clr} + e0^{clr}, (M+m) + Q^{-1}(L)\sqrt{V_{clr} + vclr}\right) \qquad (18)$$

where M, V, and $E0_{clr}$ are the aggregate traffic load, variance of the aggregate

5   traffic load, and sum of the lossless effective bandwidth to meet the CLR

requirement, i.e.,

$$M = \sum m_i \qquad (19)$$

$$V_{clr} = \sum m_i\left(e0_i^{clr} - m_i\right) \qquad (20)$$

$$E0_{clr} = \sum e0_i^{clr} \qquad (21)$$

In step 115, C_{alloc} is set equal to the value determined for C_{clr} in step 110. In

step 120, effective bandwidth for the new connection as well as all the existing

10   connections to meet the CDV requirement $e0^{cdv}$ is computed by

$$e0_i^{cdv} = \frac{p_i}{2}\left[1 - \frac{\sigma_i}{1-x_i} + \sqrt{\left(1 - \frac{\sigma_i}{1-x_i}\right)^2 + 4\sigma_i\frac{x_i}{1-x_i}}\right] \qquad (22)$$

where $x_i = m_i/p_i$ and $\sigma_i = d * C_{alloc}/(b_i \log(1/\alpha))$. In step 125, the variance of the aggregate traffic load V_{cdv} and the sum of the lossless effective bandwidth $E0_{cdv}$ to meet the CDV requirements are computed by

$$V_{cdv} = \sum m_i \left(e0_i^{cdv} - m_i \right) \tag{23}$$

$$E0_{cdv} = \sum e0_i^{cdv} \tag{24}$$

5   In step 130, the required bandwidth to meet the CDV requirements is computed by

$$C_{cdv} = \min\left(E0_{cdv}, M + Q^{-1}(\alpha)\sqrt{V_{cdv}} \right) \tag{25}$$

In step 135, the required bandwidth reqBW is determined by max (C_{clr}, C_{cdv}) and in step 140 the required bandwidth reqBW determined in step 135 is compared

10   to the capacity of the port, or link, C_p, in the system through which the calls are passing. If the required bandwidth reqBW is greater than the capacity of the link C_p, then in step 145 the call is rejected. If the required bandwidth reqBW is not greater than the capacity of the link C_p, then in step 145 the call is accepted and the state

variables of the system are updated to include the accepted call as follows:

$$N = N + 1$$
$$M+ = m$$
$$V_{clr}+ = vclr$$
$$E0_{clr}+ = e0^{clr}$$

5

where N is the number of established connections. Specifically, the number of connections N is increased by one, the aggregate traffic load M is updated by adding the new connection's sustainable cell rate (SCR) m to the previous aggregate load, the aggregate variance of the traffic load V_{clr} is updated by adding the new

10 connection's variance $vclr$ to the previous aggregate variance, and the sum of the lossless effective bandwidth $E0_{clr}$ is updated by adding the new connection's lossless effective bandwidth $e0^{clr}$ to the previous effective bandwidth. Thus, in accordance with the present invention, perfect state bookkeeping is performed when a new connection setup is requested to determine if the call will be admitted or denied.

15 Fig. 3 illustrates in flow chart form a method for performing perfect state bookkeeping, in accordance with the present invention, when a call release is requested. In step 160 the effective bandwidth to meet the CLR requirement $e0^{clr}$ is computed using Equation (16) for the connection of the call to be released. In step 165, the variance of the traffic load $vclr$ for the call to be released is computed using

20 Equation (17). In step 170, the state variables are updated as follows:

$$N = N - 1$$
$$M- = m$$
$$Vclr - = vclr$$
$$E0_{clr}- = e0^{clr}$$

25

Specifically, the number of connections N is decreased by one, the aggregate traffic load M is updated by subtracting the sustainable cell rate (SCR) m of the call to be released from the previous aggregate load, the aggregate variance of the traffic load V_{clr} is updated by subtracting the variance $vclr$ of the call to be released from the previous aggregate variance, and the sum of the lossless·effective bandwidth $E0_{clr}$ is updated by subtracting the lossless effective bandwidth $e0^{clr}$ of the call to be released from the previous effective bandwidth.

In step 175, the required bandwidth to meet the CLR requirement is computed by

$$C_{clr} = \min\left(E0_{clr}, M + Q^{-1}(L)\sqrt{V_{clr}}\right) \qquad (26)$$

In step 180, C_{alloc} is set equal to the value determined for C_{clr} in step 175. In step 185, effective bandwidth $e0^{cdv}$ for the connection of the call to be released as well as all the existing connections to meet the CDV requirement is computed using Equation (22). In step 190, the variance of the aggregate traffic load V_{cdv} and the sum of the lossless effective bandwidth $E0_{cdv}$ to meet the CDV requirement are computed using Equation (23) and (24), respectively. In step 195, the required bandwidth C_{cdv} to meet the CDV requirements is computed using Equation (25). In step 200, the required bandwidth reqBW is allocated, where reqBW = max (C_{clr}, C_{cdv}), and in step 205 the call is released.

Figs. 4A and 4B illustrate in flow chart form a method for approximate state bookkeeping, in accordance with the present invention, when a connection setup is requested. The approximate state bookkeeping is similar to the perfect state bookkeeping described in Figs. 2A and 2B, except that it is not required to re-

5   compute $e0^{cdv}$ for all existing connections when a connection setup is coming.

When a new connection setup c_i request, described by p, m, and b, comes in, in step 220 the effective bandwidth to meet the CLR requirement $e0^{clr}$ is computed using Equation (16). In step 225, the variance of the traffic load $vclr$ is computed using Equation (17). In step 230, the required bandwidth C_{clr} to meet the CLR

10   requirement is computed using Equation (18). In step 235, C_{alloc} is set equal to the value determined for C_{clr} in step 230. In step 240, effective bandwidth $e0^{cdv}$ for the new connection to meet the CDV requirement is computed using Equation (22). In step 245, the variance of the traffic load $vcdv$ is set equal to $m(e0^{cdv} - m)$ and $e0cdv$ is assigned the value of $e0_{cdv}$ computed in step 240 for each connection c_i. In

15   step 250, the required bandwidth to meet the CDV requirements is computed by

$$C_{cdv} = \min\left(E0_{cdv} + e0^{cdv}, (M + m) + Q^{-1}(\alpha)\sqrt{V_{cdv} + vcdv}\right) \qquad (27)$$

In step 255, the required bandwidth reqBW is determined by max (C_{clr}, C_{cdv}) and in step 260 the required bandwidth reqBW determined in step 255 is compared to the capacity of the port, or link, C_p, in the system through which the calls are

20   passing. If the required bandwidth reqBW is greater than the capacity of the link C_p,

then in step 265 the call is rejected. If the required bandwidth reqBW is not greater than the capacity of the link C_p, then in step 270 the call is accepted and the state variables of the system are updated to include the accepted call as follows:

5

$$N = N + 1$$
$$M + = m$$
$$Vclr+ = vclr$$
$$E0_{clr}+ = e0^{clr}$$
$$V_{cdv}+ = vcdv$$
$$E0_{cdv}+ = e0_{cdv}$$

10   Specifically, the number of connections N is increased by one, the aggregate traffic load M is updated by adding the new connection's sustainable cell rate (SCR) m to the previous aggregate load, the aggregate variance of the traffic load V_{clr} is updated by adding the new connection's variance $vclr$ to the previous aggregate variance, the sum of the lossless effective bandwidth $E0_{clr}$ is updated by adding the

15   new connection's lossless effective bandwidth $e0^{clr}$ to the previous effective bandwidth, the aggregate variance of the traffic load V_{cdv} is updated by adding the new connection's variance $vcdv$ to the previous aggregate variance, and the sum of the lossless effective bandwidth $E0_{cdv}$ is updated by adding the new connection's lossless effective bandwidth $e0^{cdv}$ to the previous effective bandwidth. Thus, in

20   accordance with the present invention, perfect state bookkeeping is performed when a new connection setup is requested to determine if the call will be admitted or denied.

Fig. 5 illustrates in flow chart form a method for performing approximate state bookkeeping, in accordance with the present invention, when a call release is

25   requested. In step 300, the effective bandwidth to meet the CDV requirement $e0^{cdv}$

is obtained for the call to be released c_i, which is the value for $e0cdv$ computed when the call is set up.   In step 305, the variance of the traffic load $vcdv$ is calculated using the value for $e0^{cdv}$ obtained in step 300. In step 310 the effective bandwidth to meet the CLR requirement $e0^{clr}$ is computed using Equation (16) for the connection of the call to be released. In step 315, the variance of the traffic load $vclr$ of the call to be released is computed using Equation (17). In step 320, the state variables are updated as follows:

$$N = N - 1$$
$$M^- = m$$
$$Vclr^- = vclr$$
$$E0_{clr}^- = e0^{clr}$$
$$V_{cdv}^- = vcdv$$
$$E0_{cdv}^- = e0^{cdv}$$

Specifically, the number of connections N is decreased by one, the aggregate traffic load M is updated by subtracting the sustainable cell rate (SCR) m of the call to be released from the previous aggregate load, the aggregate variance of the traffic load V_{clr} is updated by subtracting the variance $vclr$ of the call to be released from the previous aggregate variance, the sum of the lossless effective bandwidth $E0_{clr}$ is updated by subtracting the lossless effective bandwidth $e0^{clr}$ of the call to be released from the previous effective bandwidth, the aggregate variance of the traffic load V_{cdv} is updated by subtracting the variance $vcdv$ of the call to be released from the previous aggregate variance, and the sum of the lossless effective bandwidth $E0_{cdv}$ is updated by subtracting the lossless effective bandwidth $e0^{cdv}$ of the call to be released from the previous effective bandwidth.

In step 325, the required bandwidth to meet the CLR requirement is computed using Equation (26). In step 330, the required bandwidth C_{cdv} to meet the CDV requirements is computed using Equation (25). In step 335, the required bandwidth reqBW is allocated, where reqBW = max (C_{clr}, C_{cdv}), and in step 340 the

5   call is released.

The methods of the present invention are implemented in software and, for an ATM or IP network, are to be executed within each access terminal of the network. Fig. 6A illustrates an exemplary access terminal 400 connected to a network 420 by a feeder line 422 and a plurality of distribution lines 408 for

10   customer connections or subscriber ports. The access terminal 400 can be located in a central office or at a remote location. The access terminal 400 includes at least one microprocessor 402, memory circuit 404, and multiplexer/demultiplexer 406. It should be appreciated that an access terminal may contain numerous microprocessors, but only one microprocessor 402 is illustrated. Moreover, the

15   exact architecture of the access terminal 400 is not important as along as it can implement the methods of the present invention as described with respect to Figs. 1-5. As is known in the art, the micro-processor 402 controls and coordinates the operations of the access terminal including, but not limited to, the call processing and power control functions. The micro-processor 402 and

20   multiplexer/demultiplexer 406 will implement the call admission control methods of the present invention as described with reference to Figs. 1-5.

Fig. 6B illustrates in block diagram form a configuration system that includes a daisy chain arrangement of multiple access terminals 400-1, 400-2 and 400-3 as described with respect to Fig. 6A. In this configuration each access terminal 400-1, 400-2 and 400-3, or shelf, is assigned a portion of the bandwidth, i.e., capacity, of

5   the primary feeder 422 connected to network 420, such as for example an ATM network. While three access terminals are illustrated in Fig. 6B, the invention is not so limited and any number of access terminals may be provided. The methods according to the present invention allow each access terminal to have independent bandwidth allocation while ensuring that at provisioning time the summation of the

10   assigned bandwidth to each shelf does not exceed the bandwidth of the primary feeder 422. Thus, each access terminal can function independently of the others in the daisy chain. For example, for a system with a feeder 422 bandwidth of C and a daisy chain having n shelves, the methods according to the present invention ensure the following is complied with:

15   $$C = shelf\_PCR_1 + shelf\_PCR_2 + shelf\_PCR_3 + \ldots + shelf\_PCR_n \qquad (28)$$

Reference has been made to embodiments in describing the invention. However, additions, deletions, substitutions, or other modifications which would fall within the scope of the invention defined in the claims may be implemented by those skilled in the art and familiar with the disclosure of the invention without

20   departing from the spirit or scope of the invention. Also, although the invention is described as implemented by a programmable controller, preferably a microprocessor running a software program, it may be implemented in hardware, software, or any

combination of the two. All are deemed equivalent with respect to the operation of

the invention. Additionally, while the invention has been described with respect to

ATM/IP networks, the invention is not so limited and may be used with any type of

communication system, including for example wireless communication systems.

5   Accordingly, the invention is not to be considered as limited by the foregoing

description, but is only limited by the scope of the appended claims.

10

15